Qualitative assessment

of the

Canadian Commercial Transportation Fuel Ethanol Potential

Agriculture Canada

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The objective of Grains 2000 is to foster greater industry input in the formulation of domestic agricultural policy. Views expressed in Grains 2000 reports are therefore those of the authors and do not necessarily represent those of Agriculture Canada.

1 Executive summary

This is a qualitative assessment of ethanol transportation fuels feasibility in the Canadian market place. The underlying questions are:

- Is there a viable opportunity for transportation fuel ethanol in Canada?
- If so, how can it be established?

This report attempts to address only the more specific current questions of the National Grains Bureau. The range of these questions and the breadth of the issues can not be handled in depth within the time and budget constraints established. Discussing the potential for a new industry is not a simple matter. This is especially the case for fuel ethanol where the business is both in competition with, and integrated within the existing fuel business.

There has been a great deal of change recently in the transportation fuel market. There are improved prospects for fuel ethanol integration with elements of the current gasoline distribution and marketing system. Better economics, the growing environmental focus, current government policies, new more cost effective Canadian technology, a logical approach to linking the business functions, and many other factors can now create opportunity for ethanol.

Ethanol fuels present new agricultural market potentials for grain, or cellulose. The opportunity can contribute to diversification. Ethanol is the only practical transportation fuel that can contribute to sustainable development. Wheat and barley are currently the most likely feedstocks, with cellulose a potential long term raw material. New products, and markets equivalent to 500 -1000 kilotonnes per year of cereal grains might be achievable. The fuel market is very different from feed markets. The agricultural industry would need to consider supply and pricing practices similar to those used for competing feedstocks to this fuel industry.

There are potential road blocks to progress. These appear to be manageable if the basic economics are favorable. Some of the issues follow. Old economics indicate ethanol is too costly as a gasoline component. There is a lack of a coordinated effort. Fuel marketing expertise is absent and the refiners have generally not been approached in a supportive way. The agriculture industry's pricing and supply position is of potential concern.

Ethanol has been used extensively as a transportation fuel both internationally and in Canada. There are no significant technical problems. While all the alternative fuels have advantages, ethanol stacks up well so long as it is competitively priced. When compared to gasoline and the other alternative fuels, ethanol's environmental impact is a major advantage.

Our work indicates:

- Current economics need development.
- Some market assessment work is required.
- There is an important role for government, including a clear statement on alternative fuels and ethanol blends.
- The barriers to sales of the blend can be reduced by customer supportive marketing practices, a quality product, and reliable supply.
- An initiative can be launched to attract the required participation and establish a national fuel ethanol component in transportation fuels.
- An independently led consortium would be most effective to integrate the activity.

2 Introduction

This is a qualitative assessment of the feasibility of transportation ethanol fuel in the Canadian marketplace. The underlying questions are:

- Is there a viable opportunity for transportation fuel ethanol in Canada?
- If so, how can it be established?

This report does not answer these questions but attempts to address only the current questions of the National Grains Bureau in Winnipeg. The report content is generally commercial rather than technical and can lead to a second phase of assessment prior to the decision to support commercial development.

The terms of reference call for the following;

> "prepare and present a report which identifies changes in specific elements/issues that may suggest the need for a reassessment of the potential for ethanol/ethanol products to be integrated into the Canadian fuel system. The report should emphasize the identification of current constraints, the impact of proposed changes in the regulatory/policy environment and effects on Canadian agriculture".

The report should also " outline a second phase project to develop a detailed "business plan" to assess the net benefit to Canadian agriculture and Canadian society and to suggest private/public actions to overcome constraints to the achievement of a national fuel ethanol/ethanol product component in transportation fuels. This outline would prioritize areas of work, recommend the composition of a proposed project team, and estimate time requirements and costs."

The elements commented upon include;

- Changing factors that make the reassessment of fuel ethanol necessary.
- Current development constraints.
- The environmental impacts and effect of proposed regulation.
- The potential for grain/cellulose consumption and the effects on Canadian Agriculture.
- Competing fuels from renewable and non renewable sources.
- The technical and economic viability of ethanol fuel blends.
- Impact of the Canadian U.S. Trade Agreement.
- An outline of the work necessary to assess the benefits and over come constraints.
- Recommendations to prioritize the work, and organize a project team.

Some of the content in this report has been previously published or presented in current articles and recent speeches on alternative fuels by the author. The information has been reviewed with some interested firms to help develop a consensus of opinion and support for the business, when it proves commercial.

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The report content is generally commercial rather than technical. Commercial business development methods can show the approach that would successfully move ethanol from biomass aggressively into the Canadian fuel markets.

The material in this report has been organized to suit the National Grain Bureau's needs. Discussing the potential for a new industry is not a simple matter. This is especially complicated for fuel ethanol

where the business is both in competition with, and integrated within the existing fuel business.
Good work has been completed on all fronts to help pave the way for alcohol fuel.

- Canadians have used the fuel successfully in their existing motor vehicles with excellent performance. Consumer reaction to ethanol fuel has not been negative.
- Blending, distribution, and retail channels have been established under the V-Plus brand, and Mohawk stations currently retailing alcohol blends.
- A new Ontario production facility is operating. It is the fourth in the country currently manufacturing commercial ethanol. Mohawk is expanding.
- More advanced new Canadian fermentation technology is near the commercial stage.
- The Canadian automotive vehicles manufacturers do not exclude alcohol in their vehicle warrantees. Acceptance has also been expressed in many discussions with each manufacturer, the Motor Vehicle Manufacturing Association, and at the emission reduction opportunity public hearings convened by Environment Canada and Transport Canada in Ottawa in September of 1989.
- Promotion has been persuasive, both through technical seminars and the media.

The following U.S. initiatives in the area of motor fuels have had a significant influence on recent Canadian action.

- The removal of lead
- The reduction in gasoline volatility
- The use of MTBE
- The acceptance of ethanol
- The introduction of higher octane gasolines in the market place
- Promoting lower sulfur diesel

All the transportation sector environmental initiatives we are now seeing in Canada are coming from the United States. In spite of these initiatives, the Canadian fuel ethanol industry is not developing in line with the U.S., nor as quickly as some might expect.

3 The changing situation - factors that can create opportunity

There has been much recent change in the transportation fuel market. Some of these changes create a window of opportunity allowing the integration of ethanol with elements of the current gasoline distribution and marketing system.

3.1 More favorable economics, the most significant of all current developments, could show that ethanol fuel blend produces good profits in gasoline. Significant opportunities exist which can lower ethanol cost, perhaps to as low as 16 cents per liter.

3.2 The growing environmental focus can provide a new demand for fuel grade ethanol from renewable sources. This focus has created environmental priorities, consumer interest, new government policy and proposed regulatory measures.

3.2.1 The growing consumer environmental interest creates an opportunity for ethanol. Mohawk, the only Canadian transportation fuel ethanol supplier, is producing at its plant capacity and has an expansion planned. A recent national poll by Angus Reid indicates that, in the interest of protecting the environment, the majority of Canadians would pay 5 cents/litre more for gasoline to decrease air pollution. None of the environmental arguments are particularly strong technically, however it is very important to note that perception will rule the day. This has been the case with both the current reduction in gasoline vapor pressure, and the imminent "virtual elimination" of lead in gasoline. Ethanol is perceived to stack up well from an environmental point of view. It can take on the role of the environmentally friendly gasoline blend. Promotion will be required. The degree of acceptance needs to be determined through commercial market assessment.

3.2.2 Government environmental priority is growing. Proposed regulatory measures which can promote a demand for fuel grade alcohol from renewable resources include greenhouse gas reduction, ozone reduction, removal of the manganese fuel additive MMT and especially the CO2 reduction initiatives. There are no policies nor regulation changes foreseen that are constraining the development of ethanol fuels. None of the current proposals nor potential control options being assessed under the new Canadian Environmental Protection Act (CEPA) will have a negative impact on ethanol. This is important because any business opportunity that has merit is pleased to at least start with a lack of such constraints.

The Environment minister emphasizes the need for CO2 reduction in his 1989 Climate Institute conference speech by asking,"How can the use of alternative fuels be promoted?" The unprecedented initiatives of CEPA, international protocols, and harmonization with U.S. fuel control regulations indicate that government is willing to consider implementing new regulations.

The current environmental policies, the regulations currently in place, programs already implemented like the removal of lead in gasoline, and the proposed regulatory direction all tend to tighten octane supply. Most proposed changes are in the direction of removing components from gasoline and diesel. Both oxygen containing chemicals (oxygenates) and natural gas are significant transportation fuel alternatives as a result. Ethanol could help replace the current gasoline components such as toluene that potentially pose environmental risks. Aromatics (such as benzene, toluene, and poly aromatics) are on the CEPA priority substance list. Although they have not been assessed as yet, there are concerns about their carcinogenic nature. Further restrictions on gasoline components could be regulated within the next 3 years, forcing replacement with other octane streams. Ethanol, and, ETBE the ether derivative of ethanol, can be strong replacement candidates.

On the other hand, few of the currently proposed policies and regulations act as specific incentives for ethanol. There are incentives in place, mainly provincial, but the proposed policy and regulatory agenda does not appear to contain new substantive incentives in this area.

3.3 Agriculture policy. The priorities of diversification and environmental sustainability can be advanced through the ethanol fuel opportunity. Both new markets and product opportunities can be created. Perhaps an additional 500 kilotonnes of grain per year, or new cellulose forest products could be sold. Using renewable biomass for fuel aids sustainable development.

3.4 Significant C02 reduction can be gained through non fossil fuel use. This is a compelling argument for nuclear power generation. However ethanol can play a part. Overall global warming will not be significantly affected by using ethanol in Canadian gasoline, but ethanol will make a contribution to CO2 reduction. The magnitude is a function of the amount of gasoline replaced by ethanol, the fuel's mileage and the CO2 absorbed by biomass. There could be a significant reduction in C02 from ethanol replacing gasoline.

3.5 Canadian sustainable development can be "show-cased" through this initiative. Showing Canadian action on sustainable development is a priority of many ministries including Energy, Environment, Agriculture and Transport.

3.6 New Canadian technology is now available that can lead the way to lower conversion costs for ethanol manufacturing. This area is another federal priority, of significant interest to Industry Trade and Technology as well as other ministries.

Ethanol research in the past 10 years has dropped ethanol costs from 95 cents/litre to 35 cents/litre from starch feedstocks. It now appears cellulose feedstocks produce ethanol which is competitive with conventional fuels at the refinery gate. Some recent work indicates that an 80M liter/yr plant costing $ 55M could fit the market requirement, be large enough to achieve the necessary economy of scale, and should generate $ 4M annual profit at capacity. A 20M liter/yr plant capacity costing $ 20M could be marginal. Modern instrumentation and operational controls are critical.

The simultaneous saccharification and fermentation process along with continuous reaction has great promise. New Canadian technology has excellent costs at the present time but the 95% yields attainable might be boosted to 98%. In addition lower energy requirements and reduced fermentation times provide incentive to use the technology commercially. Depending on feedstock prices, ethanol might be in the 13 to 16 cent / liter area. With the 3% yield increase and plant throughput improvements, Canadian ethanol technology appears to produce ethanol competitive with gasoline components and with the current alternatives of both MTBE and toluene.

This Canadian technology is almost at commercialization. The work is virtually complete with commercial feasibility confirmed. However, some further bench work and pilot plant runs are needed to assure no surprises in some other areas such as improved yields, multiple biocatalyst systems and the provision for bulk starter cultures.

The focus to date has been on pure ethanol. Mixed alcohols can be produced to add to the value of the fuel alcohol. This co-production of the higher alcohols also may reduce fuel production cost.

3.7 Harmonization with U.S. is a major emphasis of the federal government in both environmental and economic initiatives.

3.8 Energy supply is tightening. The gas bubble is reducing. The Canadian commitment to supply more U.S. energy requirements tightens Canadian supply. As exports increase we may not have the same reserves for Canada. Practical energy alternatives, including ethanol, along with conservation and resource development are solutions.

3.9 Diminishing returns on improvements have been reached as gasoline and the motor vehicle have been optimized over the past 20 years. A new departure is required for a significant improvement. Oxygenates and NGV can help provide this "step" change.

3.10 Fuel marketing expertise is available to help show ethanol's advantage to the existing fuel sales channels. In the past the arena has been combative.

3.11 Linking the business functions is now possible. There is a logical approach. The people are available, supportive marketing thrust can be planned, and the drive is present to fill the gaps between the business functions. This provides the ethanol opportunity within the existing infrastructure.

4 Effect on Canadian agriculture

A fuel ethanol initiative in Canada will not have a large overall effect on the agriculture sector but the new sales could be significant.

The U.S. can be used as one model to predict the potential consumption and trends in Canada. In the United States, the U.S. Department of Agriculture data indicates 8.6 million tons of surplus corn is converted to fuel ethanol producing 3.2 billion liters of anhydrous ethanol for fuel blending. Blends represent about 8% of all retail gasoline in the U.S..

The oil industry projects Canadian gasoline consumption at about 34.5 billion liters with 20 billion used in Ontario and Quebec. This could represent 280 million liters of ethanol or 750 kTe (kilotonnes) of grain in Canada with 160 million liters (430 kTe) potentially consumed in Ontario and Quebec. These volumes should not be counted upon initially. If ethanol could be in all gasoline volumes at perhaps 1% (880 kTe), or at 8% in half the premium (590 kTe), or in half the independents gasoline (500 kTe), Canadian cereal grain sales could increase about 1%.

The Grains and Oilseeds Branch November '87 paper, entitled Regional Feed Grain Price Impacts With Increased Ethanol Production, suggests a price increase of approximately 2% in the west and 6% in the east for a 3% ethanol blend in all Canadian gasoline, and a minimal change in supply for the increased sales. In addition, some studies assume regional grain will be supplied for regional ethanol use. These assumptions may not be currently valid.

In practice the ethanol plant could be attracted to lower feed cost locations with the ethanol shipped to the gasoline terminals for blending. A quick look at grain and ethanol distribution costs would show if the plant could be constructed in the West to supply Eastern markets. This may be a good potential.

Ethanol plant construction and operation may also help reduce regional disparity if the location is logical from business basics. Using marginal land for specific types of feedstock might make the ethanol plant attractive in some less developed areas.

Fuel alcohol is another export opportunity for the Canadian farmer.

Wheat or barley will be the obvious first feedstock options for earliest market entry. Cooperation and interest from the agriculture community is excellent. Strong initiative and leadership is being provided by some sectors of agriculture and it can be expected to continue. However, if the grain industry is not able to generate an innovative approach to pricing, this ethanol fuel business would be advised to concentrate on the development of the cellulosic feedstocks.

Lignocellulosic biomass, such as wood based material, may be a more favorable long term feed stock for fuel ethanol production than sugar or starch crops. These low cost feed stocks provide the best margin to cover conversion costs for efficient processes. The potential for regional development, and ample supply of this "new" crop make cellulose attractive in the long term. Cellulose might be competitive at a 20 cent a liter refinery gate gasoline price. The feedstock economics around short rotation high yield forestry plantations may confirm the advantage of cellulose. There are current process reliability questions that need answers.

Feedstock selection will be based mainly on feedstock cost component in the ethanol and the by-product markets. Technology should not control feedstock except for cellulose in the short term.

World wide price trends affect ethanol's long term potential. More countries in the world are becoming self-sufficient in grain supplies and are requiring more protein feeds. If constant dollar grain prices decline and protein's relative value to grain increases, there could be a significant opportunity to use grain in ethanol production.

Once the feedstock is picked and hence the by-product known, definitive work will show the quantitative effect on Canadian agriculture.

5 Constraints on ethanol development-road blocks to progress

Ethanol fuel's entry in Canada has not progressed as well as it has in the United States. The regulatory process, the legal system, the significant urban environmental problems, the systems of reciprocal support and lobbying, even the acceptance of change and risk-taking on new ventures are all very different in the U.S.

There are some specific factors for the slower ethanol development in Canada. They should be considered issues not constraints. These issues can be addressed. Stating what needs to be done is easy but it would take time and expertise to accomplish the work. The following issues are significant.

5.1. Ethanol is perceived as too costly as a gasoline component. This may not be the case today. Current economic returns are not well defined.

5.1.1 Most of the published cost studies completed out side the industry, (such as those by U.S. Dept of Agriculture, Ontario energy ministry, Canadian Energy Research Institute etc.) infer that ethanol is at a cost disadvantage in gasoline. These studies generally compare ethanol against a perceived average gasoline cost rather than the cost of competing alternative gasoline components.

The wide-spread perception that fuel ethanol is to expensive to produce from grain also comes from the fact that many of the ethanol plants built after the oil price shock in the United States are uneconomical at current oil prices. These plants were built based on subsidies or favorable tax treatment and are too inefficient to survive with oil prices below $38 U.S. per barrel. Ethanol costs have not as yet been optimized with best available technology and incremental feedstock costs.

There is lack of current data.We need to develop the facts.

5.1.2 On the other hand, refiners have proposed that ethanol be priced at 84% of unleaded gasoline (since 1.19 liters of ethanol are equivalent to 1.0 liters of gasoline on a distance basis) less any added handling and service costs. The less expensive butane is removed to maintain vapor pressure. However, it is also stated that without this vapor pressure constraint alcohol might command a price at 125% to 135% of unleaded gasoline. Although these claims need confirmation for Canadian gasoline specifications, ethanol value could be significantly different than the oil industry's current suggestions.

When pricing ethanol, all the value added advantages should be taken into account.These are listed in section 7.3. The price of ethanol can be higher than the cost of gasoline but still be cost effective for many retailers.

5.1.3 The agricultural feedstock pricing and supply approach is of concern. The feedstock could be 50% of the fuel cost. This is the single most important factor determining the viability of this business.

The opportunity to establish this industry diminishes if feedstock availability is not guaranteed, or if economics for this opportunity are based on tightening feed-grain supply and increased prices. The best attraction agriculture can bring to promote interest in this venture is a feedstock price with no surprises until the project is on its feet.

5.2. The refiners' backlash. The refiners' concern goes beyond price. The Canadian oil and gasoline supply is available and reliable. Billions of dollars in capital has been invested in resource development and oil refineries. The refining and marketing industry is earning low returns. Neither the loss of market share to a competing fuel, nor the development of an expensive ethanol fuel channel within the oil business is particularly attractive to refining companies.

The transport of ethanol blends in pipelines is a difficult issue. Although currently unpopular with the refiners that control the lines, it can be technically practical especially in lines carrying jet fuel.

5.3. Fuel marketing expertise is absent amongst most of the current champions for ethanol as a transportation fuel.

There is too little emphasis on marketing and a lack of understanding of this sector. The advantages of ethanol have not been sold to the gasoline marketer. The true value of ethanol in gasoline has not been presented. These advantages are generally not well understood by many of the proponents of ethanol who, with very few exceptions, are outside the gasoline industry. Negotiation has not taken advantage of the full value of ethanol in gasoline. Successful entry into the competitive gasoline markets is difficult without first hand experience in recognizing, stimulating and satisfying the transportation fuel demand. Experience is required for pricing, distribution, branding, promotion, service, advertising, and selling. A strong market focus in the plan is essential to avoid failure.

5.4. Good product knowledge is lacking. Ethanol fuel can be at a serious disadvantage. Transportation fuels are complex products. It took 7 years to develop the fuel expertise to reach the point the industry is at now. If the potential ethanol sellers don't understand the product side of their business, one should not be surprised if acceptance is blocked. This information is available.

5.5. Unknowns and change are problems for any new opportunity. It is a special problem for ethanol fuels because gasoline satisfies the consumers' needs and there is no great requirement for the new product. There is a residual feeling, which was valid in the past, of fuel quality risks, poor customer acceptance and unnecessary high cost.

5.6. The adversarial mood between the established gasoline producers and what is currently a competing alcohol fuel lobby is strong. There is an orientation towards government funding, subsidization and regulation to force the fuel into the market. The whole strategy has been a confrontational, a combative, and an antagonistic campaign against gasoline. It is not a wonder that the refiners act defensively.

The approach to date is often seen as an attempt to intimidate the current fuel sellers and coerce them into participation. Through promotional programs on the negatives of gasoline, and lobbying for regulation or special treatment for oxygenates, one sometimes gets the impression of a desperate adversary, lacking a competitive niche in the market place. It can be shown that ethanol helps solve the gasoline retailers' problems and satisfies their needs. Knowing your customer and servicing the need can result in success.

5.7. There is a lack of integration of the various activities necessary from biomass production through to alcohol use in the consumer's vehicle. There is a lack of a coordinated effort between a feed stock supplier, technology development, the plant constructor and operator, blenders, distributors, and retailers of the product.

There is no solid integrated business plan, with a critical path scheduled, for all integrated activities. If a new ethanol plant was built in this environment, one is likely to end up "all dressed up with no place to go". Cash flow problems could be inevitable. It would not be the first time this type of chemical or fuels project failed.

Integrating the various business functions will unite all the ethanol efforts and help smooth the way to success.

5.8. Reliability of supply. The gasoline retailers feel that some of the current Eastern Canadian ethanol manufacturing plans lack the necessary quality assurance and supply reliability. This perception can be resolved if the fuel industry sees its concerns addressed. If a fuel ethanol initiative is lead by an established company, that has demonstrated its commitment to quality reliability and service, this issue will be no more significant than it is with MTBE.

5.9. Although North American based manufacturers accept alcohols some off shore based firms, especially some European based auto companies, are in opposition to the fuel. This is of less consequence overall due to their position in the marketplace and their ability to adapt, at a cost, if the market requires it. They would be more concerned if alcohol was legislated into most of our gasoline.

6 Possible impact of the Canadian U.S. Trade agreement

The trade agreement is not a basic issue in determining the long term viability of an national ethanol transportation fuel business. The case can be made for both a positive and negative influence. However, in balance, the trade agreement is not likely to have a major impact.

It may be cheaper to locate a plant in the United States and supply the fuel back into Canada. The lower capital cost in the U.S. for chemical plants has been consistently established over the last 30 years. Labour rates and other costs are also less south of the border. Corn, currently preferred by some processors, could be less expensive due to the countervail duty. On the other hand, attractive Canadian feedstock availability and pricing were reasons for the establishment of much of the current Canadian commodity chemical infrastructure.

The potential of starting up Northern tier mothballed U.S. plants to supply eastern gasoline markets can be neutralized. If a major more efficient Canadian plant is established before one comes on stream in the U.S., it should preclude a startup south of the boarder. Tariff on gasoline and gasoline components are not controlling.

Government financial support for this new industry might affect Canadian exports by creating negative trade action by U.S. interests. Subsidies are provided in the United States, however even equal subsidization will not win the support of the U.S. protectionists. This is probably not an issue because there is a good route to a significant export potential. However, safe economics should be based only on Canadian sales.

At this time the trade agreement is not seen as an important issue affecting the building of an efficient Canadian ethanol business. Feedstock price and distribution cost will likely be the main factors.

7 The viability of ethanol

7.1 Ethanol's transportation fuel performance

Pure ethanol fuel has been well established, in Brazil for example, and has few of the technical problems associated with pure methanol (flame visibility, etc.). However, the fuel is so different from gasoline that only blends at or below 10% are expected to enter the retail market in Canada. Ethanol in gasoline modifies the fuels properties and affects the nature and quality of both the vehicle exhaust and evaporative emissions.

Since the ethanol blend can meet gasoline specifications, the consumer sees no reduction in driveability characteristics.

Gasoline with ethanol keeps the engine cleaner than with the same gasoline alone.

Actual tests show fuel economies from 0.5 mpg reduction to a mileage improvement. Ethanol is higher density at 6.6 pounds / U.S. gal than gasoline at 6.0 to 6.5 pounds / U.S. gal at 60 F. The energy content however at 76k BTU/U.S. gal is less than gasoline at 115k BTU/U.S. gal. Power from the fuel is proportional to its lower heating value, octane and latent heat of vaporization. Theoretically 1.19 liters of ethanol power a vehicle as far as one liter of gasoline. However the lower latent heat of vaporization reduces the temperature of the air/fuel mix and the degree of vaporization as it enters the cylinder. This can improve fuel economy and power by increasing the amount of atomized fuel entering the cylinder. Generally mileage improvement is experienced on cars that run rich.

Alcohol fuels can be used to advantage in new engines with higher compression ratios were the fuel can help reduce the tendency to pre-ignite and burn too quickly. As a result power and fuel economy can be improved through using ethanol as a octane booster. Research and motor octane ratings of regular gasoline are 92 and 82 while ethanol rates at 129 and 96. Toluene is at 115 and 98. Ethanol has a significant octane advantage.With ethanol's boiling point of 70 C, Reid vapor pressures of a 10% ethanol-gasoline blend can increase by 0.5-1.0 PSI above the gasoline component. Less gasoline butane must be used, especially during summer months, to maintain Canadian General Standards Board (CGSB) volatility specifications.

At 70 F, the 10% ethanol-gasoline blends can hold about 0.3% water without phase separation. Higher alcohols and other components such as MTBE and ETBE can increase the water tolerance.

7.2 Ethanol's environmental performance

Ethanol's biggest environmental asset is the 59% net reduction in C02 because of the absorption of C02 during the production of biomass.

Ethanol use will also reduce CO by up to 25% from many cars. Ethanol's effect of reducing the fuel to air ratio on engines adjusted for gasoline reduces CO. Older engines without adaptive learning closed loop technology to optimize performance can expect lowering C0 emissions by between 10% and 30%. However this emission source will disappear, even without the use of ethanol, when the vehicle fleet turns over.

Ethanol could help replace the current gasoline components such as toluene that may have environmental risks. If regulations are passed within the next 3 years ethanol can be a strong replacement candidate.

The arguments around all the other environmental issues (aldehydes, evaporative emissions, higher or lower nitrogen oxides (NOX) etc.) are of little consequence. There are conflicting views, much within the limits of accuracy of the data.

The largest criticism is the perception that aldehydes might be produced and at a significant level. This is not an environmental issue. Aldehyde production would be negligible, if it is produced, and even the small amount generated would be trapped on the front end of current exhaust catalysts. The test results are well established. Aldehyde emissions from new vehicles with 3 way catalyst are expected to be substantially lower even on blends, when compared to older vehicles operating on gasoline.

None of the arguments supporting ethanol for environmental reasons are particularly strong technically. Ethanol would be blended at up to 10% in some fraction of the total gasoline in Canada. All of the transportation fuels we burn currently contributes only 4% to the world greenhouse gases. However it is very important to note that perceptions will rule the day rather than technical facts. This has been the case with both the current reduction in gasoline vapor pressure, and the imminent "virtual elimination" of lead in gasoline. The ethanol blend will be accepted as the environmentally friendly transportation fuel. Promotion will be required. The degree of acceptance needs to be researched.

7.3 Alternative fuel comparisons with ethanol

Ethanol and other alternative fuels compete in various ways with each other and with gasoline and diesel. Gasoline is sold mainly on the basis of price, station location and appearance, service and promotion. Product differentiation (engine cleaners, octane level, special additives etc.) is generally short lived if it changes market share. The other sellers will adjust and sell the same product.

About 70% of Canada's gasoline is sold by the three majors (ESSO, PetroCanada and Shell). The remaining 30% is split relatively equally between the independents and the regional refiners.

Refiners wish to use their own feedstocks as much as possible. However, if there are octane shortages in the short term, other chemicals will be used. Canadian refinery capital programs will generate the octane from oil in the longer term. Their need for new component streams to replace those currently under attack will be developed from within their own refinery as existing cat-crackers are replaced or upgraded, as more Canadian heavy crude is moved through hydrocracking units, and as the refiner focuses on higher octane processing options.

There are advantages to integrating an ethanol or an ETBE operation into the refinery configuration. This is an excellent approach but is outside the scope of this report.

Each fuel has its strengths, weakness and opportunity in the market. Since most of the alternatives have some merit, promotion of the specific fuels by the separate constituencies have as much impact on sales as the fuels' properties. They all are competing for a share in the same rather inelastic transportation fuel market.

Gasoline, diesel and the other alternatives present a threat to ethanol growth. The alternatives compete on the basis on economics, driveability, environmental issues, and ease of integration into the existing fuel infrastructure. The market opportunities for ethanol lie in the gasoline sales drives stated above and a combination of the following: octane, environmental improvement, cost, public interest, ease of handling, and special value added features (eg. detergent, deicing, fuel density, driveability, mileage).

The potential for ethanol use can be evaluated by comparing the technical, commercial, and environmental attributes of each of the alternative fuels.

Gasoline

Gasoline is an excellent transportation fuel that is well established in the market. It will be impossible to dislodge gasoline as the fuel of choice and difficult to penetrate the market with new fuels without support from existing gasoline suppliers. It is not practical to assume that ethanol will be added to all Canadian gasoline. A market niche exists for ethanol if it does not compete "head on" but is used to enhance the performance and marketability of gasoline. This is especially important during ethanol's market entry.

Contrary to what most reports on alternative fuels have stated, lead phase down will not create the opportunity for ethanol. There is no octane shortage as a result of the phase out of lead from gasoline in Canada. In fact some refiners are promoting higher octane blends and are able to provide the fuel. Refinery capital projects are ahead of demand. There will be some short term dislocations especially with smaller or un-upgraded refineries. On the other hand, the removal of MMT and a significant restriction of toluene in gasoline, if regulated before 1993, would have serious impact on the Canadian refining industry.

Diesel

There could be a significant ethanol opportunity in diesel substitution. There are a number of advantages to using ethanol including reduction in the diesel exhaust problem and control of other chemicals such as cyclic hydrocarbons. The potential ethanol volume is large and market entry less difficult. This could be investigated as a major opportunity for ethanol sales.

NGV

The use of natural gas for vehicles (NGV) has been proven in over 300,000 vehicles in countries such as New Zealand, Italy, and Canada over the last decade. There are no unresolved technical problems. Natural gas is now sold through self-serve stations by the major retailers and many regional gasoline suppliers in Canada.

There are no original equipment manufacturer plans to provide the vehicle hardware necessary to use the fuel. Sufficient incentives are not present in the U.S. The technology is as efficient as that for gasoline but NGV conversions will continue to be an expensive consideration when switching to this fuel.

Although NGV can be produced from biomass, it is mainly produced from fossil fuels. NGV is not generally considered a renewable fuel. It is the cleanest burning fuel and less polluting than ethanol because the combustion products are water, carbon dioxide and carbon monoxide. There is no aldehyde formation.

From the marketing viewpoint NGV requires a retail dispensing infrastructure that is currently not able to support the expected growth. NGV costs for each retail station are about $250K. The special nature of gas utility rate determination brings these costs in line with revenue generated.The current NGV fuel tank capacity is about 5 equivalent gallons of gasoline and restricts the driving range to less than 200 km.

From personal driving tests there is little or no driving differences between NGV and Gasoline. The loss of power reported is about as perceptible as driving with a couple of passengers.

NGV and ethanol perform equally well in vehicles. Ethanol blend requires less change.

The price of NGV at the pump is roughly 60% of gasoline. Retailers can make the same return on NGV as they can on gasoline.

MEOH

Current technical data shows that methanol blends can be used effectively without loss of performance. However, it is highly unlikely that pure methanol or M85, will enter the Canadian market in the foreseeable future.

Ethanol has technical advantages over methanol. Ethanol is easier to integrate into the gasoline system. Water up to 0.3% can be tolerated without phase separation. Acidity is not as pronounced, ethanol is higher density and mileage is slightly better. Ethanol blending problems are somewhat less than Methanol.

Methanol is not the oxygenate of choice in Canada.

MTBE

This ether is well established as the oxygenate of choice in gasoline markets in North America. It has been well marketed from within the industry and is well accepted when a higher cost gasoline component is required.

MTBE is the most natural choice of the current oxygenate alternatives. The product has been used

with excellent results for at least three years by most Canadian refiners. MTBE is completely miscible, requiring no special handling through the marketing system. Concentrations up to the Sunoco waiver level of just under 12% can be pipelined without incident. It is often incorporated in the gasoline without the knowledge of the distributor nor the consumer. At low concentrations, ethanol should have no technical disadvantages if it is moved by truck. MTBE has the advantage when pipelining is required.

While MTBE offers significant environmental benefits over gasoline, an assessment has not yet been initiated under the CEPA program.

Some U.S. refiners have added MTBE production facilities. The three MTBE plants proposed for Canada could have oil refiners as participants. This is especially likely because isobutylene, a refinery stream, is a major raw material for MTBE.

Nova has announced they will use their methanol in MTBE plants which they intend to build through joint ventures to provide this gasoline component. MTBE would be the most significant and widest used alternative fuel competitor to ethanol. A Sarnia plant has been considered for the last 3 years. Access to isobutylene, the Novacor (Sarnia plant) isobutylene purification requirement which can produce MTBE as a co product, the refinery situation, along with Nova's captive methanol helps to increase the potential building of an MTBE facility. Moving methanol to Sarnia at a reasonable price is a challenge. However it might move at transfer pricing if it was considered an internal supply. U.S. and western Canada locations also make some sense for Nova.

MTBE should command a price near toluene.

MMT

The current use of the manganese fuel additive (MMT) in Canada is under attack because of the Ethyl Corp. waiver application in the U.S. American based motor vehicle manufacturers would rather continue to keep this gasoline additive out of the U.S. fuel and see it banned in Canada so there would be fuel standardization.

Removal of MMT will create major disruption for Canadian refiners. Since it adds over one octane point to gasoline, MMT removal would tighten the octane supply significantly and would be a major blow to the industry's current planning.

This chemical is probably environmentally benign since manganese is required for health and the levels in gasoline are so low. However, in its pure form MMT is toxic and environmental perception issue may be developing that could result in harmonization with the U.S. and the removal of MMT from Canadian gasoline. Removal of MMT from the market place is far from certain. The impetus to ban MMT will come from the U.S. automotive manufacturers. It will not be found to be an environmental hazard in the Canadian environment. If MMT is removed, a 1994 time frame might be expected.

Aromatics

Benzene, currently below 3% in gasoline, is likely to be regulated perhaps as low as 1% in the next couple of years. In most peoples view, it is a carcinogen. This chemical is not deliberately added to gasoline and it is not relied upon for its octane although it does make a contribution. Restricting benzene in fuels will require the extraction of aromatics by refineries at a cost of about one billion dollars. More toluene will also be available as a result of the extraction. The net effect of this regulation and the subsequent round of refinery upgrading will not only be benzene removal, but modern refineries with upgraded octane options.

Ethanol could help replace the current gasoline components such as toluene if this aromatic is found to pose environmental risks. There is some data to indicate toluene breaks down to benzene at the tail pipe. Aromatics are on the CEPA priority substance list. Although they have not been assessed as yet, there are concerns about aromatic use. Toluene can be as much as 30 or 40% of a high octane gasolines. If aromatics were regulated at 25%, similar to Jet fuel there is no question that it would force either use of lower octane gasoline, replacement with other octane streams, or yet another refinery major capital program.

ETBE

ETBE is a better gasoline component than MTBE. The properties of ETBE are closer to those of

gasoline. The low latent heat of vaporization precludes any cold start problems. ETBE lowers the vapor pressure of gasoline significantly. ETBE allows for the addition of more low cost butane than does the alcohol. The blending octane number for ETBE is about the same as that for ethanol. It could be used to lower volatile organic chemicals (VOC) and the ozone subsequently produced.

Since the process of making ETBE and MTBE are essentially the same, the value of ethanol in ETBE would compete with the price of methanol after adjustments are made for performance differences.

EPA currently allows 12.7% ETBE blends representing 5.77% ethanol in the gasoline. Ethanol volumes are reduced because of the isobutylene required.

If it is economically feasible, using ethanol to produce ETBE for the market place would eliminate the problem of acceptance of ethanol and could maximize the alcohol sales.

A plot of MTBE price history relative to gasoline, plus the ETBE value added over MTBE, could give the ETBE price. Both ETBE and MTBE capital and production costs (exclusive of raw materials) should be similar. If this is fact, back calculating the ethanol feedstock price should show an approximate value of ethanol in the ETBE market.

A separate study should be done on ETBE because of its obvious immediate gasoline industry acceptability and its expected profitability. The pricing section of this study should include the work necessary to quantify the market price of ETBE relative to MTBE based on the better properties, added performance, and handling advantages.

8 Conclusions

8.1. Ethanol fuel blends could be successful in Canada on their own merits. All the components are available for successful development of national ethanol fuel industry. Economics are expected to be reasonable. However, after five years of business development experience implementing transportation fuel programs CANATRON has a realistic understanding of the issues. The industry has learned many important lessons as we have developed products and integrated alternative fuels into the Canadian transportation fuel market.

Experienced fuel industry people are required and organization is necessary to establish this niche market in the existing gasoline infrastructure.

8.2. Action is required to confirm the viability of this Canadian fuel ethanol opportunity and attract the private sector to develop the commercial potential. There have been many good reports written since 1985 on this opportunity. We contend it is time to take action.

Quick organization and decisive implementation is the best way to maximize the preference for ethanol blends. Action should be taken now before the opportunity is lost to other fuel options, to long term imports, or massive oil refinery capital programs. For ethanol to meet the market demand, this opportunity needs to be assessed now.

8.3. A detailed formal plan needs to be developed with three significant separate steps;

- confirm the potential,
- attract commercial interest,
- develop the national ethanol component in transportation fuels.

8.4. A government development initiative is required to attract private participation.

8.4.1 Government initiatives should

- confirm the validity of a Canadian ethanol transportation fuels component,
- determine what government support is required in the shorter term,
- assess in what form and for how long financial support, if any, might be required.

A credible assessment of benefits must be completed to provide the necessary information for government decision making, and attract gasoline retailers to participate in an ethanol transportation fuels business. The current potential needs to be assessed and presented, from a business development point of view, to the essential business sectors. It is imperative that the work be done with both standard practices and resources usually used by the industry to assess such opportunities. The work must be done in a way that industry issues are addressed, by using resources with experience in gasoline and alternative fuels from market survey work through to the economics.

The assessment should be completed in the standard sequence to minimize cost and achieve the shortest turn around time.

Assess the market potential first.

If it is positive, complete the technical component.

Then the financial section of the assessment can be completed.

We have included a general plan outline in the appendix to this report based on this approach. The outline covers the areas necessary to confirm the validity and develop the opportunity, but only initial steps need to be taken to attract commercial interest and investment.

8.4.2. Government policy can have a major impact on the Canadian independent business interest. A statement of support for Canadian ethanol, expressed by the Energy, Agriculture and Environment ministers would encourage more private initiative. The recent statement of strong support for the establishment of a fuel ethanol industry in Queensland by the State Government in Australia is one example. Another example of such initiative is President Bush's forceful supportive statement last summer.

8.4.3. Policy and regulation will not be the primary factors considered in the construction of a plant. There are two basic investment considerations. To proceed, this industry must be economically sustainable without long term government support, or it must be essential enough to Canadian interests to justify this support. Ethanol fuel is not perceived as an essential industry. A successful site location will depend mainly on the feedstock, energy costs, support services, and transportation costs and not on location-specific government capital incentives. A western Canadian plant location may be practical. If the private sector sees the fundamentals are met and proceeding is logical, Western Diversification funds could be attractive. Policy or regulations that effect revenue or variable costs are most significant. Construction or capital incentives have less impact.

8.4.4. Depending on the new economics, government regulation or subsidies may or may not be necessary to attract investment. Regulation of oxygenates in gasoline would be welcomed by an ethanol producer if it helped ensure sales. However, it is too early to determine if this is necessary to make a successful business, or even if potential regulations would result in any preferential impact for ethanol. It is unlikely any provincial or federal government would intervene in the market place by regulating one oxygenate over another. It places government in the position of influencing the market and the products sold. New government manufacturing support, tax relief or regulation could be premature without completion of an up to date assessment, and a well supported implementation plan to establish a viable commercial industry. The new trade agreement will not have an overall significant impact on this opportunity.

8.4.5. The opportunity for policy and regulation harmonization should be taken. It can help activate a coordinated initiative. Other ministries both provincial and federal are interested in some of the same issues. The Ontario ministries of both Energy and the Environment are interested in alternative transportation fuels and ethanol in particular. Federal ministries such as Energy Mines Resources are actively discussing options to reduce CO2 levels and to fund new work. Environment Canada has demonstrated a leadership role in transportation fuel areas. Transport and other ministries could have major roles to play. Manitoba and other provinces have provided leadership. Ontario is currently reviewing its alternative fuel positions. We conclude that the first step toward ethanol policy harmonization could be a jointly sponsored assessment. It might be better to maintain control in one Federal ministry for efficiency.

8.5. Coordination is needed. There are a number of ways to integrate the current efforts to develop a national transportation fuel ethanol industry. Of all the options reviewed, the most effective would be a consortium of the best commercial partners that can work together to manage all the functions from feedstock supply to fuel sales.

Government could stimulate a coordinated effort through participation in the work recommended and, if the analysis is favorable, by making a statement of support as suggested. Private funding can then be attracted and the full team can be assembled to commercialize this national renewable fuels opportunity. The organizational functions that must eventually be brought together include Technology, Engineering, Manufacturing, Marketing, Distribution, Sales, Finance, and Government.

8.6. The agricultural pricing and supply approach is critical to successful market development. The feedstock cost is the single most important economic factor determining the viability of this business.

Agricultural products and markets could diversify into the fuel industry if agriculture can adapt to the new opportunity. The agricultural industry would need to be flexible enough to attract this new customer base away from the products competing against ethanol.

The pricing of grain into different markets as diverse as fuels and food require different pricing formulae. These market demands are independent and unrelated. Agriculture could supply them both. There must be recognition of the need for biomass feedstocks to compete with alternative feedstock sources for ethanol fuels. Diversification into dissimilar markets can often result in good prices in one market when the other is depressed. If, over the long

run, grain producers could find the flexibility and a new vision based on market responsiveness, and freedom to manage their operations in response to different market signals, they should be successful in acquiring this additional market.

Grains sold as a feed stock to an ethanol producer should be contracted in someway so that the ethanol fuel industry has some assurance that the raw material will float with the ethanol price within this industry. A price indexed to rack gasoline or crude oil could be discussed. A fixed price for some period might be attractive. The ethanol producer would pay a premium if some of the ethanol price risk is shared.

Grains are the preferred feedstocks for ethanol. If the above issues are not addressed satisfactorily, in the long term an ethanol producer will move the feedstock supply to cellulose. The current unknowns are greater for cellulose, the risks are higher, but the rewards in the form of cheaper feedstocks could be persuasive. The best promotional incentive agriculture can bring to an ethanol fuel partnership is feedstock pricing with no surprises, until the project is on its feet.

8.7. Feedstock stability is important especially for a fledgling industry. Supply should be guaranteed through long term grain contracts. The alternative would be for ethanol producers to acquire sufficient growing land, or engage growers as partners in the commercial fuel consortium.

8.8. ETBE is a prime candidate as a fuel component because of its superior properties and acceptance by the gasoline industry. It could be more costly than ethanol and require more capital, but it is certain that larger volumes could be sold. ETBE should be costed to determine if ethanol's best opportunity is as a fuel, or a fuel feedstock.

9 Recommendations

We recommend;

9.1. That because the business sector must be attracted to develop and operate this industry, the information presented in this report could be re-compiled to be more focused to the technology, manufacturing, marketing, financial and other sectors. This information could also be presented in an issues oriented format.

9.2. That government funding of independent assessment work be initiated. CANATRON has recommended a plan outline. Although the outline covers the areas necessary to confirm the validity and develop the opportunity, only initial steps are required in some of the general areas defined to attract commercial interest and investment. This plan outline and initial steps are attached as an appendix to this report.

9.3. That after the independent assessment, an organization be developed to integrate and coordinate all the commercial functions. Establish a consortium to plan and implement the development. Government initiative could be integrated, or one ministry could spearhead the development.

9.4. That the process and product technical work be completed.

9.5. That a clear Federal statement be issued on alternative fuels and the advantages of ethanol blends to Canadians to promote interest in both industry and the consumer. Since fuel ethanol appears to support so many of the current governments priorities, since it is a popular initiative, and since negative response is well defined and limited, this verbal support should be forth coming. It would add a significant boost to private efforts to address the public agenda.

9.6. That those promoting ethanol development acquire the gasoline marketing expertise to collect market data, and complete the assessment work for both the ethanol and the by-products market strategies. If marketing is not in place before the capital is spent, one can expect low ethanol returns after the product is available. Some attention should be directed to the 60% of the Canadian gasoline market which is in Ontario and Quebec. Much of this market is concentrated in the Windsor-Montreal corridor. Letters of interest with the potential customers should be sought early in the process to justify the cost of further work.

9.7. That product application knowledge be acquired by ethanol promoters. Understanding gasoline and the effect of ethanol blends is important if ethanol is to be a wide-spread success in Canada.

9.8. That the requirement for non monetary and monetary government support be determined by completing new economics to assess the currently expected revenues (price and volumes), costs (feed stock, expense, and distribution), and plant capital sized for the market expected.

9.9. That the work necessary to develop the business plan be completed to attract private sector interest.

10 Appendix

Second phase project outline

Establish policies
- Objectives
- Strategy
- Risks

Review prior assessments
- Search literature
- Solicit input – public, government, industry (as necessary)

Complete marketing components
- Price
- Consumer
- Product
- Competition – competitors and products
- Market segments
- Distribution
- Forecast – market size, growth, and net backs
- Promotion
- Service
- Selling

Complete technology work
- R and D required
- Competing processes assessment
- Process design
- Detailed engineering
- Plant studies – location, construction, labor, environmental, etc.
- Product technology – gasoline component, blends.

Develop financial data
- Sales plan revenues
- Manufacturing plan costs
- Estimated total costs
- Estimated financial needs
- Cash flow projection
- Balance sheet projection
- Profit and loss projection

Plan the organization
- Structure
- Criteria
- Motivation
- Communication
- Responsibilities

Decide on the alternatives
- Feedstock – wheat, barley, corn, cellulose
- Product – ethanol, ETBE
- Process batch/continuous, yeast/bacterium
- Market – eg 1% in all gasoline or 10% in selected markets
- Location

Develop business plan
- to attract private investment and show the approach

Establish project control
- Over all accountability
- Decision making
- Expenses
- Progress measurement

Details of some first steps

There are only three items that need to be reviewed to complete a preliminary look that the opportunity for a national fuel ethanol/ethanol product to be integrated into the Canadian fuel system:

- Determine what ethanol is worth to the blender as a gasoline component.
- Determine the price that ethanol will bring at the pump, at various volumes, in the different retail markets.
- Determine the cost to attract consumers to the blend and the potential volumes

However, once the opportunity proves to be feasible on this basis, it is expected the following would need to be documented in business terms to attract private investment.

Marketing The viability of this project hinges on the ethanol margin and the volume that can be sold. If marketing is not in place before the capital is spent, one can expect low ethanol returns after the product is made available. The following information is required.

- The price ethanol blends can bring, at the pump, at various volumes, in the different Canadian markets.
- The costs necessary to attract the Canadian consumer to the blend.
- Ethanol's worth as a gasoline component to the refiner, the blender, and retailer.
- The best ethanol market and distribution strategy.
- Market data for the by-product market strategies.

From the above analysis

- Measure size of the the market.
- Estimate market share expected and best segments.
- Project volumes and prices.

Technology New Canadian technology is very near commercialization but it is not well enough demonstrated to justify full commercial scale up. Low capital and production costs depend on completing this work. If the plant is built without newer technology the new plant might not be a low cost producer.

R and D technology work should include;

- Lab work to take the proven new technologies to the next level of optimization. Work should include: increased productivity through biocatalyst immobilization, improved bacterial fermentation with superior tolerance yield and productivity, and other initiatives.
- Pilot plant test runs to confirm the improved yield and conversion rate in the continuous process with different feedstocks (cereals vs cellulosics).

Product technology work should include;

- Performance work with a laboratory such as ORTECH.to complete mileage tests, assessment of the use of hydrous ethanol as used in Brazil, and to test ETBE.
- Complete the Ontario Transport and Consumer and Commercial Relations Ministry (MCCR) test work to prove acceptability for Ontario sale.
- Acquire an MCCR waiver of the existing oxygenate limit in Ontario.

Plant capital estimates are required for the volume determined in the marketing section.

Economics To determine the viability of the opportunity the economics by year for 10 years is required. This means that the revenues (price and volumes), the costs (feed stock, conversion, and distribution), and the capital cost is required for the market volume expected

Organization Establish a team to integrate and coordinate all the commercial functions. Expertise in each of the following areas is required Technology, Engineering, Constructing, Manufacturing, Marketing, and Financing. Clear definition of each of the roles and responsibilities should be constituted. Over all authority needs to be agreed upon. Once the specific opportunity is defined a simple participant criteria can be developed to help establish the best potential team. Then their interest can be solicited to develop the commercial venture. A short list of the best of the interested participants in each functional area can be made early in the work.

Two key organizational elements have generally been lacking in past work:

a] the marketing expertise. The knowledge needed includes:

- A solid understanding of the gasoline retailers' buying habits.
- Knowing how ethanol meets 5 of the gasoline retailer's needs, how ethanol can create a strategic product differentiation, how a refiner can solve some problems and increases his market. Knowledge of gasoline pricing.

b] the product application knowledge. A few specifics are listed here.

- Gasoline quality issues affected by ethanol.
- Driveability.
- Knowledge of the base blend components, procedures, and control of the blending facilities.
- CGSB standards, specifications, and how the consensus standards are set.
- Knowledge of the different seasonal requirements for the fuel, and how additive packages differ for the different gasoline components, including ethanol.